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THE EFFECT OF EXERCISE ON THE HÆMOGLOBIN WITH REFERENCE TO THE VALUE OF REST IN THE TREATMENT OF ANÆMIA.

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THE observations made by G. Oliver and the writer, and published by the former in the Croonian Lectures for 1896,[1] have shown the occurrence of a diurnal physiological variation in the blood of healthy subjects, a fall in the percentage of hæmoglobin, corpuscles, and of the "worth" of the corpuscle taking place during the day, and a rise during the night. vid Chart I Examination of 650 observations on two subjects gave an average daily variation in hæmoglobin of 7.3 per cent. (7 4 per cent. day fall and 7.2 per cent. night rise); in the volume of the corpuscles of 4.3 per cent.; and, consequently, a variation in the "worth" of the corpuscle which averaged 5.9 per cent. (5.7 per cent. day fall and 6.1 per cent. night rise). The fall in "worth" is an indication of actual loss of hæmoglobin, in addition to the apparent loss resulting from dilution of the blood by fluids ingested during the day; a loss which is probably brought about by the wear and tear of the process of oxidation. It is interesting to note that the average night rise (6.1 per cent.) in the worth of the corpuscle is slightly in excess of the average day fall (5.7 per cent.), providing probably a slight reserve of hæmoglobin in the animal economy to meet variable calls made upon it, such as exercise, as will be seen below.

The amount of variation of the hæmoglobin almost always exceeds that of the corpuscles; hence a variation takes place in the "worth," the latter being a theoretical value obtained by dividing the percentage of hæmoglobin by the percentage volume of corpuscles.

It then became a matter of interest to determine whether the process was reversed in a subject who worked during the night and rested during the day. This was found to be the case. vid Chart II

When on day duty the blood showed the usual variation of day fall and night rise; when on night duty a day rise and night fall. It is interesting to note that the average fall in the worth of the corpuscle while on day duty (4.8 per cent.) is greater than that which occurred while on night duty (3.2 per cent.), the difference being probably accounted for by the fact that the amount of muscular work performed was distinctly less in the latter case than in the former. The effect of exercise given below tends to confirm this view.

Active Exercise.

The effect of exercise appears to be to cause a distinct fall in the "worth" of the corpuscle, or a loss of hæmoglobin.

To determine further the effect of exercise an examination of a continuous record of daily morning and evening observation of the blood of a healthy subject, extending over a

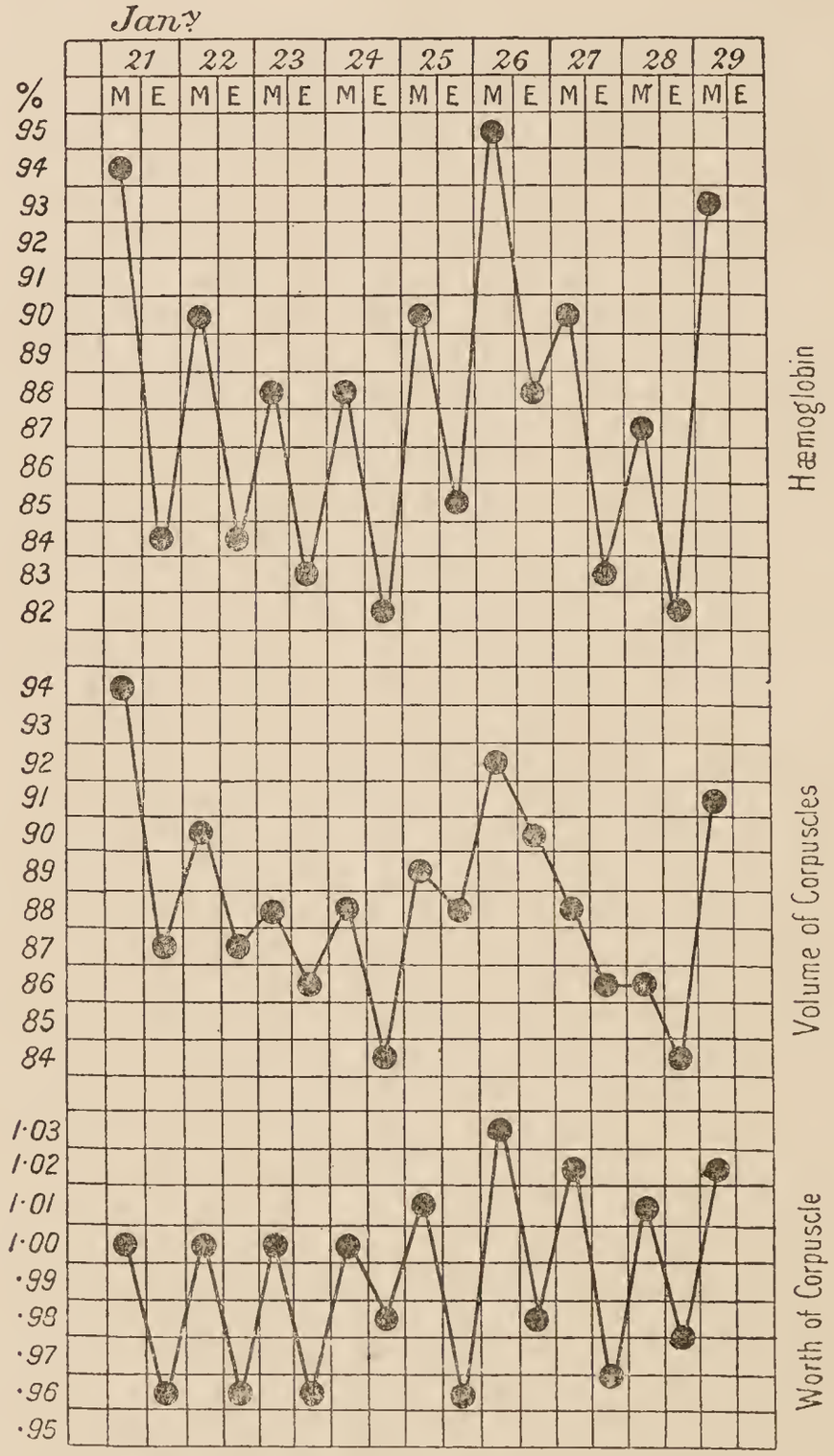

Chart 1, taken from a continuous chart of observations on another subject is a typical example of the normal daily variations.

period of three and a-half months, gave the following results. The average daily fall in the worth of the corpuscle on sixty-five days on which no exercise was taken amounted to 6.1 per cent., while the average fall on thirty-five days on which exercise was taken amounted to 9.1 per cent., showing an in-

creased fall of 3 per cent. on exercise days over no exercise days. The exercise taken varied in kind and amount, but on each of the thirty-five days it was considerable. The primary effect, then, of exercise appears to be to increase the normal day fall.

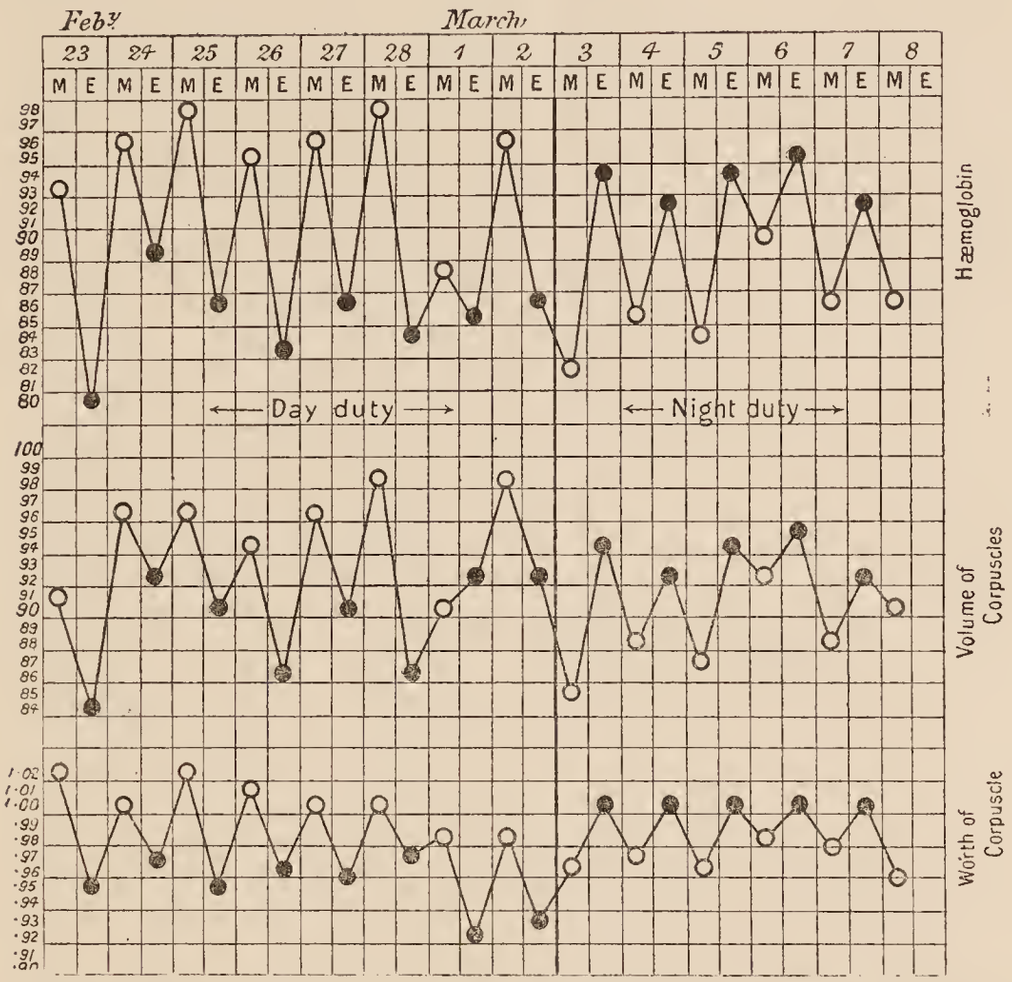

Chart II shows the result of observations made on the blood of a hospital nurse aged 22 for a fortnight, the first half of which she was on day duty, the second half on night duty. (The readings were taken immediately after rising and before retiring to rest.)

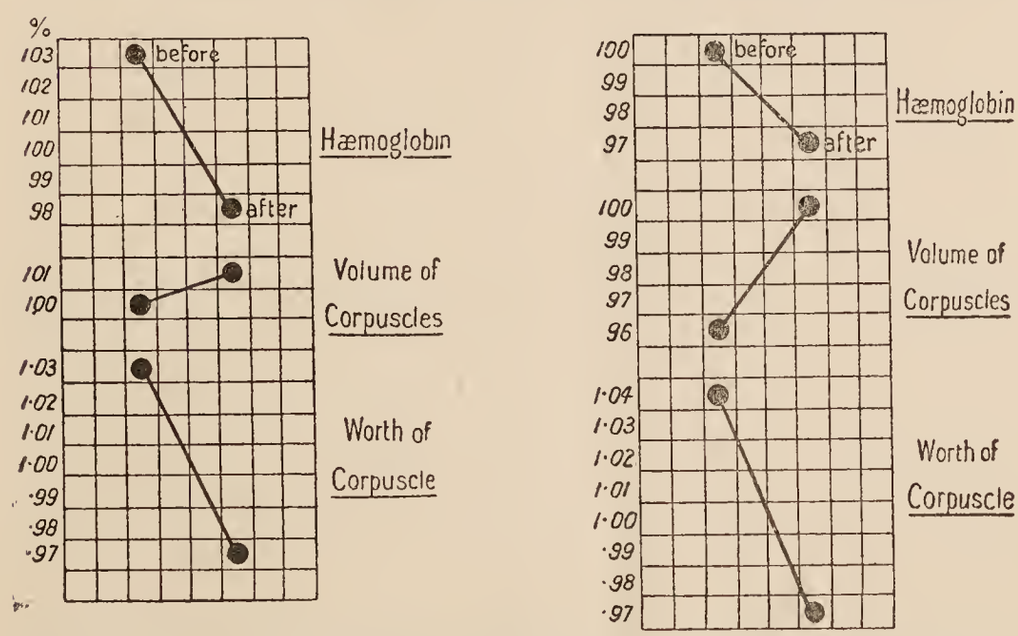

Chart III shows two examples of the result of exercise, the first (2 hrs. cycling and horse riding) without sensible perspiration, the second (2 hrs. hard tennis) with profuse perspiration.

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In each case a fall in percentage of hæmoglobin took place, with a rise in percentage volume of corpuscles, and, consequently, a fall in the "worth" of the corpuscle. Where profuse perspiration occurred the rise in percentage of corpuscles is considerable, due partly to concentration of the blood by withdrawal of fluid; hence the fall in worth in this case, the exercise being more violent, is greater than in that where no sensible perspiration took place.

Similarly the average night rise in the worth of the corpuscle that succeeded the day fall on exercise days amounted to 9 3 per cent.; whereas the night rise succeeding the day fall of no-exercise days only amounted to 6.1 per cent., a gain of 3 2 per cent. rise after exercise. Thus the augmented day fall is followed by an augmented night rise. Comparing these two we find that the average increase in the night rise after exercise (3.2 per cent.) is in excess of the average increased fall that immediately follows exercise (3.0 per cent.), which tends to show that the latter has a secondary effect in stimulating the formation of hæmoglobin.

This position is corroborated by a further examination of the record. The morning observations (when the blood is at its highest point) of the days immediately following exercise were compared with the morning observations of the exercise days themselves; and similarly the morning readings of the days following no exercise were compared with those of the previous mornings, with the object of determining whether the worth of the corpuscle was higher on the morning after exercise than on the morning of the day of exercise itself; or lower on a morning after a no-exercise day than on the morning of the no-exercise day itself, with the following results:

Morning Readings following Exercise Days compared with Morning Readings of Exercise Days themselves. Thirty five Observations.

Worth of corpuscle higher on the following morning than on previous:
10 times, or 28.5 per cent ..... average increase, 2.8 per cent.
Worth of corpuscle lower on the following morning than on previous:
15 times, or 42.9 per cent. ..... average decrease, 1.8 per cent.
Worth of corpuscle equal on both occasions:
10 times, or 28.5 per cent.

Morning Readings following no-Exercise Days compared with Morning Readings of no-Exercise Days themselves. Sixty-five Observations.

Worth of corpuscle lower on following morning:
21 times, or 32.3 per cent ... . average decrease, 2.5 per cent.
Worth of corpuscle higher on following morning:
25 times, or 38 4 per cent..... average increase, 2.1 per cent.
Worth of corpuscle equal on both occasions:
19 times, or 28.7 per cent.

Average increase of 0.7 per cent. following exercise.
,, decrease of 0.7 per cent. ,, no exercise.

This was in one way contrary to expectation, for the worth of the corpuscle read higher on the morning after exercise days than on the morning of the exercise days only ten times, whereas it read lower 15 times, being equal ten times in 35 observations. Also the worth of the corpuscle on the morning following no-exercise days read lower than on the previous morning less frequently (21 times) than it read higher (25 times), thus tending to show a greater formation of hæmoglobin as the result of no exercise than of exercise. But comparing the average amount of increase and decrease in the two cases, the reverse is seen to be the case. For the average increase after exercise days (when an increase took place) amounted to 2.8 per cent., while the average increase after no-exercise days amounted to only 2.1 per cent., a gain of 0.7 per cent. in favour of exercise. And further, the average decrease after exercise days (when

a decrease took place) only amounted to 1.8 per cent., while the decrease after no-exercise days amounted to 2.5 per cent., a gain once more (in the shape of a lesser fall) in favour of exercise of 0.7 per cent.

These figures being so small, the actual amount of gain may appear trivial, but it must be borne in mind that the cumulative effect of even so small an increment must have a powerful influence in maintaining a high average level of the worth of the corpuscle.

Thus exercise appears to result in a temporary increased destruction of hæmoglobin, but to be followed by a more than corresponding increased formation; in the healthy subject its remote effect is to stimulate the production of hæmoglobin. Possibly this may be the cause of the reserve of hæmoglobin mentioned above as being stored up to provide against contingencies. That exercise causes a not inconsiderable temporary drain on the resources of the hæmoglobin the above figures abundantly demonstrate, and the advantage of a slight reserve becomes apparent.

If these conclusions be correct, it follows that during a period when little or no exercise is taken, the average level of the worth of the corpuscle must be below that of a period of the same length during which frequent exercise is taken. The record was examined on this point with the result that during the month of August, when the subject was taking frequent hard exercise, the average of the morning readings of the worth gave the figure 1.076; during September, when a moderate amount of exercise was taken, 1.052; while during October, when circumstances compelled the subject to lead an almost absolutely sedentary life, the average amounted to 1.03.

Passive Exercise.

That passive exercise in the form of massage causes a rise in the percentage of corpuscles has been noted by several observers, among them being Melassez,[2] Chéron,[3] and K. Mitchell.[4] The latter noticed an increase in the number of corpuscles, sometimes very considerable, after massage, the maximum being reached one hour after cessation of the process, but he failed to find a corresponding increase in hæmoglobin. The rise in corpuscles he attributes to the dislodgement of large numbers that are sluggishly lingering in the by-ways of the circulation, and not available for use until disturbed by the massage.

Chart IV shows in graphic form the result of two typical experiments. They agree with the observations made by Mitchell as regards the corpuscles, the volume of which is increased, the maximum being reached one hour after light massage and two hours after heavy massage. But a corresponding rise in the percentage of hæmoglobin was noted, with, consequently, no change in the worth of the corpuscle. This result is probably due to a diminution of the total volume of the blood, fluid passing out through the capillary wall to supply the place of lymph driven on by the massage, and not to the passage of stagnant corpuscles into the active circulation. The diminution was greater after heavy than after light massage, and persisted for some hours before the displaced fluid found its way back into the general circulation, and restored the blood to its original volume. In no case was a fall in the worth of the corpuscle observed after massage. Moreover, a prolonged course of massage (one hour twice a day) on a subject whose blood decimal, or worth, was normal, had no effect in either raising or lowering it. Before the course the blood averaged $\frac{88 \text{ hæmoglobin}}{88 \text{ corpuscles}} = 1.00$ worth; after three weeks' massage it rose to $\frac{109}{109}$, and after six weeks' massage it fell to $\frac{98}{98}$, about which point

it remained. The volume of the blood was thus considerably diminished, and massage, therefore, is a powerful agent in promoting the transudation of fluid through the capillary walls, but apparently has no effect in causing destruction of the hæmoglobin.

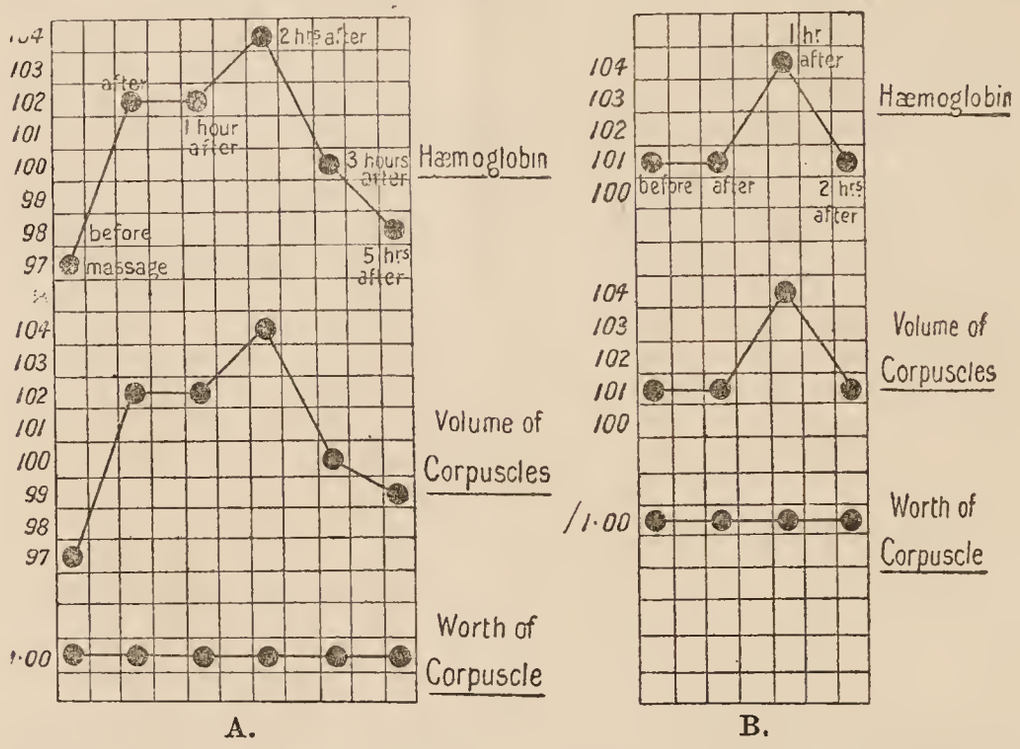

Chart IV.—Massage: A. Heavy movements (40 mins. to limbs and body). B. Light movements (40 mins. to limbs and body).

In this connection it may be noted that Lloyd Jones[5] inclines to the belief that many cases of chlorosis are characterised by an increase in the total volume of the blood, and he quotes Rubenstein[6] as holding the same opinion. The effect of massage in reducing this may account to some extent for the benefit derived by many of these patients from its use.

Effect of Rest.

The next point determined was the effect of rest on the blood. With this object the blood of a normal subject (female) was examined night and morning for a considerable period, during which she was performing her ordinary avocation, which entailed a fair amount of exercise, walking and cycling. She was then put to bed, and remained there for five days, after which she resumed her usual course.

The general average of the readings is seen to be somewhat below the normal of 100. This is usually the case in female subjects. During the first period of ten days the hæmoglobin and corpuscles showed the customary variations of day fall and night rise, the variation in hæmoglobin being relatively greater than that of the corpuscle, hence the variation in the worth of the corpuscle; the average day fall for the ten days being 4.45 per cent. During the period of five days' rest similar variations in hæmoglobin and corpuscles took place, but they are more nearly related to one another, hence the variation in the worth becomes less than before, the average fall for the five days being only 1.2 per cent. The factor of exercise being eliminated, the destruction of hæmoglobin that occurs in the day becomes much less than when the subject is leading her ordinary life. The period of ten days subsequent to rest show a return to the normal condition, the

average fall in worth being 5.35 per cent., rather greater than before. The general average of the readings of hæmoglobin and corpuscles fell somewhat during the period after rest, but as the worth remains at about its mean of 1.00 the fall merely implies a temporary increase in the volume of the blood.

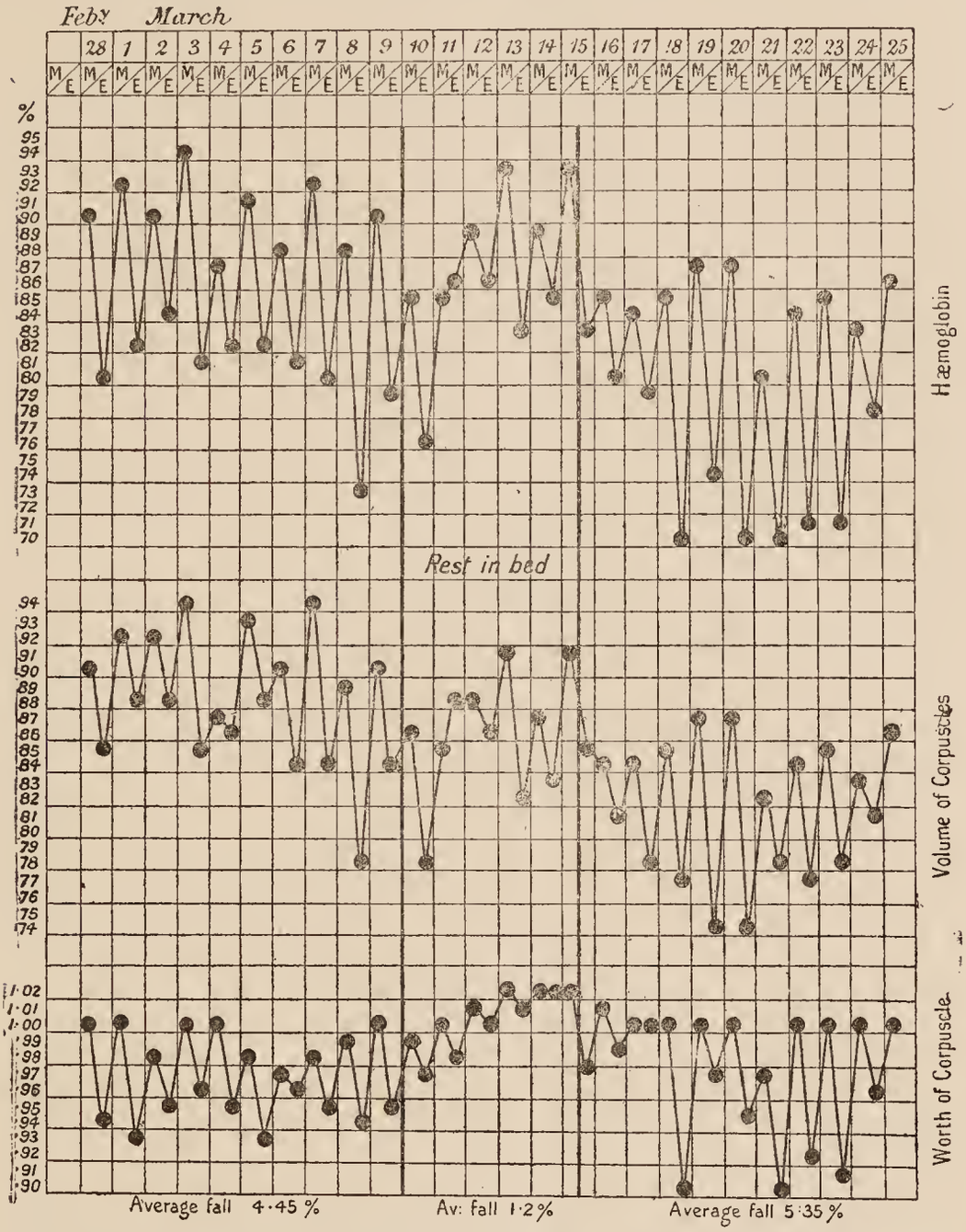

Chart v summarises the results obtained. It is a portion of the complete chart of the subject in question, and embraces ten days previous to rest, five days in bed, and ten days subsequently.

A further point of interest lies in the gradual steady increase in the worth that occurred during rest. Regarding the morning observations alone as being the readings taken when the blood is presumably at its steadiest point, a gradual rise takes place from 0.99 to 1.02, when it attained its maximum and remained there for three days, falling after activity was resumed to its mean of 1.00. Whether this high level would have been maintained through a prolonged period of rest is doubtful.

To summarise briefly the above facts:

1. There is a normal day fall and night rise in the worth of the corpuscle, representing a daily destruction and regeneration of hæmoglobin.

2. Active exercise increases the extent of the day fall and night rise.

3. Active exercise stimulates a slight over-production of hæmoglobin.

4. Passive exercise (massage) diminishes the volume of the blood, but has no effect in diminishing or increasing the amount of hæmoglobin.

5. Rest reduces the extent of the day fall in worth, representing a diminished destruction of hæmoglobin.

The bearing of these facts on the treatment of anæmia is obvious, providing as they do a physiological foundation for the well-known value of rest in bed in the treatment of that affection. Inasmuch, however, as the effect of exercise is to stimulate the production of hæmoglobin, while that of rest is to lessen its destruction, it may be objected that the conclusions to be drawn from these data are in mutual contradiction. In must be borne in mind, though, that the observations were made on normal subjects, in whom the temporary increased destruction of hæmoglobin brought about by exercise is fully met and repaired by increased formation. To complete the investigation it is necessary to determine by diurnal observation of the blood of an anæmic subject taking considerable exercise, whether the reproduction of the hæmoglobin would be sufficient to make good the loss occasioned by exercise. The undesirability of keeping a patient sufficiently long under observation without treatment has prevented me examining this point. From clinical experience we may infer with tolerable certainty that construction would fall short of destruction, or at least would not be in excess of it as is the case in health. In other words, that the already seriously diminished amount of hæmoglobin would be unable to respond to the call made upon it by exercise, so that gradually the total amount would be further lessened. Rest, on the other hand, by removing the drain, would enable the constructive process to exceed the destructive, and the store of hæmoglobin to be gradually built up.

Mode of Observation.

The instruments used in the collection of these data were the hæmoglobinometer and hæmocytometer devised by Oliver.[1]

References.

[1] Croonian Lectures, *Lancet*, vol i, 1896 [2] *Compt. Rend. Soc. Biol. Paris*, tomes cxi, cxii. [3] *Compt. Rend. de l'Acad. des Sciences*, 1895, vol. ii, No. 6. [4] Allbutt's *System of Med.*, vol. 1, p. 378. [5] "Chlorosis," by E. Lloyd Jones, p. 24. [6] "Ueber die Ursache der Heilwirkung des Aderlasses, bei Chlorose," *Wien. Med. Presse*, 1893.